

1 1. A controlled, switched laser system for
2 vaporizing a target structure on a substrate, comprising:
3 a diode-pumped, solid-state laser-assembly; and
4 a controllable switch for controlling the on/off
5 state and power level of the laser assembly;
6 the laser assembly having a laser beam output with
7 an output pulse width less than about 8 nanoseconds at an
8 operating repetition rate of about 5 kilohertz or higher,
9 and a wavelength beyond the absorption edge of the substrate
10 in order to obtain low absorption of the laser beam output
11 by the substrate;
12 whereby heating of the substrate and hence damage to
13 the substrate is limited due to the output pulse width being
14 less than about 8 nanoseconds and due to the wavelength
15 being beyond the absorption edge of the substrate.

1 2. The laser system of claim 1 wherein the output
2 pulse width of the laser beam output is less than about 5
3 nanoseconds at an operating repetition rate of about 5
4 kilohertz or higher.

1 3. The laser system of claim 2 wherein the output
2 pulse width of the laser beam output is less than about 4
3 nanoseconds at an operating repetition rate of about 5
4 kilohertz or higher.

1 4. The laser system of claim 3 wherein the output
2 pulse width of the laser beam output is less than about 4
3 nanoseconds at an operating repetition rate of about 8
4 kilohertz or higher.

1 5. The laser system of claim 2 wherein the output
2 pulse width of the laser beam output is less than about 5

202070731 010702

3 nanoseconds at an operating repetition rate of about 10
4 kilohertz or higher.

1 6. The laser system of claim 1 wherein the output
2 pulse has a peak beam power sufficiently high to evaporate a
3 metal link in a high-density memory.

1 7. The laser system of claim 1 wherein the laser
2 assembly comprises a neodymium vanadate laser.

1 8. The laser system of claim 1 wherein the laser
2 assembly comprises a neodymium:YLF laser.

1 9. The laser system of claim 1 wherein the laser
2 assembly comprises a neodymium:YAG laser.

1 10. The laser system of claim 1 wherein the laser
2 assembly comprises a laser having a cavity length optimized
3 for limiting the output pulse width.

1 11. A method of vaporizing a target structure on a
2 substrate, comprising the steps of:

3 providing a controlled, switched laser system
4 comprising a diode-pumped, solid-state laser assembly and a
5 controllable switch for controlling the on/off state and
6 power level of the laser assembly;

7 producing a laser beam output having an output pulse
8 width less than about 8 nanoseconds at an operating
9 repetition rate of about 5 kilohertz or higher, and a
10 wavelength beyond the absorption edge of the substrate in
11 order to obtain low absorption of the laser beam output by
12 the substrate; and

1 16. The laser system of claim 15 wherein the laser
2 is a tunable fosterite laser and the wavelength shifter is a
3 tuner incorporated into the fosterite laser.

1 17. The laser system of claim 15 wherein the
2 wavelength shifter is not part of the laser.

1 18. The laser system of claim 17 wherein the
2 wavelength shifter is removably insertable into the switched
3 laser system so as to enable the switched laser system to
4 operate at the conventional wavelength and at the wavelength
5 beyond the absorption edge of the substrate.

1 19. The laser system of claim 15 wherein the
2 conventional wavelength is about 1.047 μm .

1 20. The laser system of claim 15 wherein the
2 conventional wavelength is about 1.064 μm .

1 21. The laser system of claim 20 wherein the output
2 pulse width of the laser output is less than about 4
3 nanoseconds at an operating repetition rate of about 8
4 kilohertz or higher.

1 22. The laser system of claim 20 wherein the output
2 pulse width of the laser output is less than about 5
3 nanoseconds at an operating repetition rate of about 10
4 kilohertz or higher.

1 23. The laser system of claim 15 wherein the
2 wavelength shifter is a Raman shifter.

202070731.010702

1 24. The laser system of claim 15 wherein the output
2 pulse has a peak beam power sufficiently high to evaporate a
3 metal link in a high-density memory.

1 25. A method of vaporizing a target structure on a
2 substrate, comprising the steps of:

3 providing a controlled, switched laser system
4 comprising a diode-pumped, solid-state laser and a
5 controllable switch for controlling the on/off state and
6 power level of the laser;

7 producing a laser output having an output pulse
8 width less than about 8 nanoseconds at an operating
9 repetition rate of about 5 kilohertz or higher;

10 shifting the wavelength of the laser output from a
11 conventional wavelength to a wavelength beyond the
12 absorption edge of the substrate in order to obtain a
13 decrease in absorption of the laser output by the substrate
14 due to the shift in the wavelength of the laser output; and
15 directing the laser output at the target structure
16 on the substrate to vaporize the target structure.

1 26. A controlled, switched laser system for
2 vaporizing a target structure on a substrate, comprising:

3 a diode-pumped, solid-state laser assembly; and
4 a controllable switch for controlling the on/off
5 state and power level of the laser assembly;

6 the laser assembly having a laser beam output having
7 an output pulse width less than about 8 nanoseconds at an
8 operating repetition rate of about 5 kilohertz or higher,
9 and a wavelength beyond the absorption edge of the substrate
10 but shorter than 1.2 μm in order to obtain low absorption of
11 the laser beam output by the substrate;

12 whereby heating of the substrate and hence damage to
13 the substrate is limited due to the output pulse width being
14 less than about 8 nanoseconds and due to the wavelength
15 being beyond the absorption edge of the substrate, and
16 whereby good depth of focus of the laser beam output is
17 maintained relative to spot size of the laser beam output
18 due to the wavelength being less than about 1.2 μm .

1 27. The laser system of claim 26 wherein the output
2 pulse has a peak beam power sufficiently high to evaporate a
3 metal link in a high-density memory.

1 28. A method of vaporizing a target structure on a
2 substrate, comprising the steps of:

3 providing a controlled, switched laser system
4 comprising a diode-pumped, solid-state laser assembly and a
5 controllable switch for controlling the on/off state and
6 power level of the laser assembly;

7 producing a laser beam output having an output pulse
8 width less than about 8 nanoseconds at an operating
9 repetition rate of about 5 kilohertz or higher, and a
10 wavelength beyond the absorption edge of the substrate but
11 shorter than 1.2 μm in order to obtain low absorption of the
12 laser beam output by the substrate; and

13 directing the laser beam output at the target
14 structure on the substrate to vaporize the target structure;

15 whereby heating of the substrate and hence damage to
16 the substrate is limited due to the output pulse width being
17 less than about 8 nanoseconds and due to the wavelength
18 being beyond the absorption edge of the substrate, and
19 whereby good depth of focus of the laser beam output is
20 maintained relative to spot size of the laser beam output
21 due to the wavelength being less than about 1.2 μm .

1 29. The method of claim 28 wherein the laser beam
2 output has a spot size and depth of field sufficient for
3 reliable processing of target structures on a substrate
4 having a substantially non-flat surface.

1 30. The method of claim 29 wherein the laser beam
2 output has a spot size and depth of field sufficient for
3 reliable processing of target structures on a wafer having
4 approximately an 8-inch diameter, a thickness of less than
5 about 300 μm , and a substantial variation in flatness over
6 its surface.

1 31. The method of claim 28 wherein the target
2 structure vaporized by the laser beam output is about 1 μm
3 wide.

1 32. The method of claim 28 wherein the target
2 structure vaporized by the laser beam output is about 1/3 μm
3 thick.

1 33. The method of claim 28 wherein the target
2 structure comprises a metal link in a high-density memory.

1 34. A controlled, switched laser system for
2 vaporizing a target structure on a substrate, comprising:
3 a diode-pumped, solid-state laser for producing a
4 laser output with an output pulse width less than about 8
5 nanoseconds at an operating repetition rate of about 5
6 kilohertz or higher;

7 a controllable switch for controlling the on/off
8 state and power level of the laser; and

9 a wavelength shifter for shifting the wavelength of
10 the laser output from a conventional wavelength to a

2020-10-01 10:03:41

11 wavelength beyond the absorption edge of the substrate in
12 order to obtain a decrease in absorption of the laser output
13 by the substrate due to the shift in the wavelength of the
14 laser output, the wavelength shifter enabling the switched
15 laser system to operate at the conventional wavelength and
16 at the wavelength beyond the absorption edge of the
17 substrate;

18 the laser comprising optics for focusing a laser
19 spot at the conventional wavelength and also, without
20 modification of the optics, at the wavelength beyond the
21 absorption edge of the substrate.

1 35. The laser system of claim 34 wherein the
2 conventional wavelength is about 1.064 μm .

1 36. The laser system of claim 34 wherein the
2 wavelength beyond the absorption edge of the substrate is
3 shorter than 1.2 μm .

1 37. The laser system of claim 34 wherein the laser
2 comprises optics optimized for operation at the conventional
3 wavelength.

1 38. The laser system of claim 34 wherein the laser
2 comprises optics optimized for operation at the wavelength
3 beyond the absorption edge of the substrate.

1 39. The laser system of claim 34 the laser
2 comprises optics optimized for operation at a wavelength
3 intermediate between the conventional wavelength and the
4 wavelength beyond the absorption edge of the substrate.

1 40. The laser system of claim 34 wherein the
2 wavelength shifter is a Raman shifter.

1 41. The laser system of claim 34 wherein the output
2 pulse has a peak beam power sufficiently high to evaporate a
3 metal link in a high-density memory.

1 42. A method of vaporizing target structures on
2 substrates, comprising the steps of:

3 providing a controlled, switched laser system
4 comprising a diode-pumped, solid-state laser and a
5 controllable switch for controlling the on/off state and
6 power level of the laser;

7 producing a laser output having an output pulse
8 width less than about 8 nanoseconds at an operating
9 repetition rate of about 5 kilohertz or higher;

10 directing the laser output at a first target
11 structure on a first substrate to vaporize the first target
12 structure, the laser output being at a wavelength beyond the
13 absorption edge of the first substrate in order to obtain
14 low absorption of the laser output by the first substrate,
15 the laser output being focused by optics of the laser;

16 shifting the wavelength of the laser output from the
17 wavelength beyond the absorption edge of the first substrate
18 to a conventional wavelength; and

19 directing the laser output at a second target
20 structure on a second substrate to vaporize the second
21 target structure, the laser output being at the conventional
22 wavelength, the laser output being focused by the optics
23 previously used to focus the laser output onto the first
24 substrate, without modification of the optics.

1 43. The method of claim 42 wherein the second
2 target structure comprises a link formed of a material
3 selected from the group of polysilicide, polysilicon, and
4 like materials.

1 44. The method of claim 42 wherein the first target
2 structure comprises a metal link.

1 45. A controlled, switched laser system for
2 vaporizing a target structure on a substrate, comprising:
3 a diode-pumped, solid-state laser for producing a
4 laser output;

5 a controllable switch for controlling the on/off
6 state and power level of the laser; and

7 a wavelength shifter for shifting the wavelength of
8 the laser output from a first, conventional wavelength to a
9 second wavelength beyond the absorption edge of the
10 substrate but shorter than 1.2 μm in order to obtain a
11 decrease in absorption of the laser output by the substrate
12 due to the shift in the wavelength of the laser output, the
13 wavelength shifter being removably insertable into the
14 switched laser system so as to enable the switched laser
15 system to operate at the conventional wavelength and at the
16 wavelength beyond the absorption edge of the substrate;

17 whereby heating of the substrate and hence damage to
18 the substrate is limited due to the second wavelength being
19 beyond the absorption edge of the substrate, and whereby
20 good depth of focus of the laser beam output is maintained
21 relative to spot size of the laser beam output due to the
22 second wavelength being less than about 1.2 μm .

1 46. The laser system of claim 45 wherein the laser
2 output has an output pulse width less than about 8

3 nanoseconds at an operating repetition rate of about 5
4 kilohertz or higher, whereby heating of the substrate and
5 hence damage to the substrate is limited due to the output
6 pulse width being less than about 8 nanoseconds.

1 47. The laser system of claim 45 wherein the laser
2 is a neodymium vanadate laser.

1 48 The laser system of claim 45 wherein the laser
2 is a neodymium:YLF laser.

1 49 The laser system of claim 45 wherein the laser
2 is a neodymium:YAG laser.

1 50. The laser system of claim 45 wherein the laser
2 has a cavity length optimized for limiting the output pulse
3 width.

1 51. The laser system of claim 45 wherein the laser
2 comprises optics optimized for operation at the conventional
3 wavelength.

1 52. The laser system of claim 45 wherein the laser
2 comprises optics optimized for operation at the wavelength
3 beyond the absorption edge of the substrate.

1 53. The laser system of claim 45 the laser
2 comprises optics optimized for operation at a wavelength
3 intermediate between the conventional wavelength and the
4 wavelength beyond the absorption edge of the substrate.

1 54. The laser system of claim 45 wherein the
2 wavelength shifter is a Raman shifter.

1 55. The laser system of claim 45 wherein the output
2 pulse has a peak beam power sufficiently high to evaporate a
3 metal link in a high-density memory. —

1 56. A method of vaporizing target structures on
2 substrates, comprising the steps of:

3 providing a controlled, switched laser system
4 comprising a diode-pumped, solid-state laser and a
5 controllable switch for controlling the on/off state and
6 power level of the laser;

7 producing a laser output having an output pulse
8 width less than about 8 nanoseconds at an operating
9 repetition rate of about 5 kilohertz or higher;

10 directing the laser output through a removably
11 insertable wavelength shifter to a first target structure on
12 a first substrate to vaporize the first target structure,
13 the laser output being at a wavelength beyond the absorption
14 edge of the first substrate but shorter than 1.2 μm in order
15 to obtain low absorption of the laser output by the first
16 substrate while maintaining good depth of focus of the laser
17 beam output relative to spot size of the laser beam output;

18 removing the removably insertable wavelength shifter
19 from the switched laser system, in order to shift the
20 wavelength of the laser output from the wavelength beyond
21 the absorption edge of the first substrate to a conventional
22 wavelength; and

23 directing the laser output at a second target
24 structure on a second substrate to vaporize the second
25 target structure, the laser output being at the conventional
26 wavelength.

Add
A6